TABLE 3.3-1

Burst bit rates

Table 3.3–1. Burst Bit Rates

Standard Uplink	225 Kbps, 450 Kbps, 675 Kbps, 900 Kbps, 1.125 Mbps, 1.35 Mbps, ..., 28.8 Mbps
Standard Downlink	324 Mbps
Mobile Uplink	225 Kbps, 450 Kbps, 675 Kbps, 900 Kbps, 1.125 Mbps, 1.35 Mbps, ..., 28.8 Mbps
Mobile Downlink	81 Mbps
High Data Rate Uplink	191 Mbps, 383 Mbps, 574 Mbps, 766 Mbps, 957 Mbps, 1.148 Gbps, 1.340 Gbps, and 1.531 Gbps
High Data Rate Downlink	191 Mbps, 383 Mbps, 574 Mbps, 766 Mbps, 957 Mbps, 1.148 Gbps, 1.340 Gbps, and 1.531 Gbps
ISL	191 Mbps, 383 Mbps, 574 Mbps, 766 Mbps, 957 Mbps, 1.148 Gbps, 1.340 Gbps, and 1.531 Gbps

Detailed link budgets for the TSLs and the MSLs for clear sky and for heavy rain conditions are shown in Tables 3.3-2 and 3.3-3, and Tables 3.3-4 and 3.3-5, respectively. The minimum uplink bit rate is shown. Higher uplink bit rates are supported by various combinations of larger diameter (higher gain) Standard and Mobile Terminal antennas and increased Standard and Mobile Terminal transmit power. Heavy rain is defined using the Crane model as the 99.9-th percentile for temperate continental areas (region D2).

TABLE 3.3-2

TSL clear sky link budgets

	40 DEGREE ELEVATION		90 DEGREE ELEVATION	
	UP-LINK	DOWN-LINK	UP-LINK	DOWN-LINK
Peak Transmit Power (Watts)	0.0126	75	0.0093	75
Transmit Antenna Peak Gain (dB)	36	32	36	29.8
Pointing Loss (dB)	-0.5	-2	-0.5	-2
EIRP (dBW)	16.5	48.8	15.2	46.6
Frequency (GHz)	30	20	30	20
Slant Range (km)	1022	1022	700	700
Polarization Loss (dB)	0.5	0.5	0.5	0.5
Gaseous Loss (dB)	1.3	2.7	1	2.1
Rainfall Loss (dB)	0.0	0.0	0.0	0.0
Total Transmission Loss (dB)	184.0	181.9	180.4	178.0
Receive Antenna Peak Gain (dB)	32	33	29.8	33
Pointing Loss (dB)	-2	-0.5	-2	-0.5
Antenna Loss (dB)	2	1	2	1
Receiver Noise Figure (dB)	3.5	2.5	3.5	2.5
G/T (dB/K)	1.9	6.5	-0.3	6.8
Uncoded Burst Data Rate (Mbits/sec)	0.225	324	0.225	324
Required Eb/No (dB)	4.5	4.5	4.5	4.5
Implementation Loss (dB)	2	2	2	2
Required C/No (dB-Hz)	60.0	91.6	60.0	91.6
Link Margin (dB)	3.0	10.4	3.0	12.3
Peak Flux Density in 1 MHz (dBW/m^2)	-108.6	-106.4	-106.6	-105.3

TABLE 3.3-3

TSL heavy rain link budgets

	40 DEGREE ELEVATION		90 DEGREE ELEVATION	
	UP-LINK	DOWN-LINK	UP-LINK	DOWN-LINK
Peak Transmit Power (Watts)	0.64	75	0.046	75
Transmit Antenna Peak Gain (dB)	36	32	36	29.8
Pointing Loss (dB)	-0.5	-2	-0.5	-2
EIRP (dBW)	33.6	48.8	22.1	46.6
Frequency (GHz)	30	20	30	20
Slant Range (km)	1022	1022	700	700
Polarization Loss (dB)	0.5	0.5	0.5	0.5
Gaseous Loss (dB)	1.3	2.7	1	2.1
Rainfall Loss (dB)	19.0	9.0	9.0	4.0
Total Transmission Loss (dB)	203.0	190.9	189.4	182.0
Receive Antenna Peak Gain (dB)	32	33	29.8	33
Pointing Loss (dB)	-2	-0.5	-2	-0.5
Antenna Loss (dB)	2	1	2	1
Receiver Noise Figure (dB)	3.5	2.5	3.5	2.5
G/T (dB/K)	1.9	5.5	-0.3	5.9
Uncoded Burst Data Rate (Mbits/sec)	0.225	324	0.225	324
Required Eb/No (dB)	4.5	4.5	4.5	4.5
Implementation Loss (dB)	2	2	2	2
Required C/No (dB-Hz)	60.0	91.6	60.0	91.6
Link Margin (dB)	1.0	0.4	1.0	7.4
Peak Flux Density in 1 MHz (dBW/m^2)	-91.5	-106.4	-99.7	-105.3

TABLE 3.3-4

MSL clear sky link budgets

	40 DEGREE ELEVATION		90 DEGREE ELEVATION	
	UP-LINK	DOWN-LINK	UP-LINK	DOWN-LINK
Peak Transmit Power (Watts)	0.051	75	0.037	75
Transmit Antenna Peak Gain (dB)	30	32	30	29.8
Pointing Loss (dB)	-0.5	-2	-0.5	-2
EIRP (dBW)	16.6	48.8	15.2	46.6
Frequency (GHz)	30	20	30	20
Slant Range (Km)	1022	1022	700	700
Polarization Loss (dB)	0.5	0.5	0.5	0.5
Gaseous Loss (dB)	1.3	2.7	1	2.1
Rainfall Loss (dB)	0.0	0.0	0.0	0.0
Total Transmission Loss (dB)	184.0	181.9	180.4	178.0
Receive Antenna Peak Gain (dB)	32	27	29.8	27
Pointing Loss (dB)	-2	-0.5	-2	-0.5
Antenna Loss (dB)	2	1	2	1
Receiver Noise Figure (dB)	3.5	2.5	3.5	2.5
G/T (dB/K)	1.9	0.5	-0.3	0.8
Uncoded Burst Data Rate (Mbits/sec)	0.225	81	0.225	81
Required Eb/No (dB)	4.5	4.5	4.5	4.5
Implementation Loss (dB)	2	2	2	2
Required C/No (dB-Hz)	60.0	85.6	60.0	85.6
Link Margin (dB)	3.0	10.5	3.0	12.4
Peak Flux Density in 1 MHz (dBW/m^2)	-108.5	-100.4	-106.6	-99.3

TABLE 3.3-5

MSL heavy rain link budgets

	40 DEGREE ELEVATION		90 DEGREE ELEVATION	
	UP-LINK	DOWN-LINK	UP-LINK	DOWN-LINK
Peak Transmit Power (Watts)	2.55	75	0.185	75
Transmit Antenna Peak Gain (dB)	30	32	30	29.8
Pointing Loss (dB)	-0.5	-2	-0.5	-2
EIRP (dBW)	33.6	48.8	22.2	46.6
Frequency (GHz)	30	20	30	20
Slant Range (Km)	1022	1022	700	700
Polarization Loss (dB)	0.5	0.5	0.5	0.5
Gaseous Loss (dB)	1.3	2.7	1	2.1
Rainfall Loss (dB)	19.0	9.0	9.0	4.0
Total Transmission Loss (dB)	203.0	190.9	189.4	182.0
Receive Antenna Peak Gain (dB)	32	27	29.8	27
Pointing Loss (dB)	-2	-0.5	-2	-0.5
Antenna Loss (dB)	2	1	2	1
Receiver Noise Figure (dB)	3.5	2.5	3.5	2.5
G/T (dB/K)	1.9	-0.5	-0.3	-0.1
Uncoded Burst Data Rate (Mbits/sec)	0.225	81	0.225	81
Required Eb/No (dB)	4.5	4.5	4.5	4.5
Implementation Loss (dB)	2	2	2	2
Required C/No (dB-Hz)	60.0	85.6	60.0	85.6
Link Margin (dB)	1.0	0.4	1.0	7.4
Peak Flux Density in 1 MHz (dBW/m²)	-91.5	-100.4	-99.6	-99.3

Figure 3.3 - 5. MSL Heavy Rain Link Budgets

Detailed link budgets for the GSLs for clear sky and for heavy rain conditions are shown in Tables 3.3-6 and 3.3-7, respectively. The maximum bit rate is shown. Communication at any of the lower bit rates allows operation with various combinations of smaller diameter (lower gain) high data rate terminal antenna and reduced high data rate terminal transmit power. The high data rate terminals may use site diversity to provide predicted availability of 99.99% or better from virtually any location in the United States.

TABLE 3.3-6

GSL clear sky link budgets

	40 DEGREE ELEVATION		90 DEGREE ELEVATION	
	UP-LINK	DOWN-LINK	UP-LINK	DOWN-LINK
Peak Transmit Power (Watts)	0.96	0.72	0.42	0.28
Transmit Antenna Peak Gain (dB)	50	41	50	41
Pointing Loss (dB)	-0.5	-0.5	-0.5	-0.5
EIRP (dBW)	49.3	39.1	45.7	35.0
Frequency (GHz)	30	20	30	20
Slant Range (km)	1022	1022	700	700
Polarization Loss (dB)	0.5	0.5	0.5	0.5
Gaseous Loss (dB)	1.3	2.7	1	2.1
Rainfall Loss (dB)	0.0	0.0	0.0	0.0
Total Transmission Loss (dB)	184.0	181.9	180.4	178.0
Receive Antenna Peak Gain (dB)	41	47	41	47
Pointing Loss (dB)	-0.5	-0.5	-0.5	-0.5
Antenna Loss (dB)	2	1	2	1
Receiver Noise Figure (dB)	3.5	2.5	3.5	2.5
G/T (dB/K)	12.4	20.5	12.4	20.8
Uncoded Burst Data Rate (Mbits/sec)	1531	1531	1531	1531
Required Eb/No (dB)	10	10	10	10
Implementation Loss (dB)	2	2	2	2
Required C/No (dB-Hz)	103.8	103.8	103.8	103.8
Link Margin (dB)	2.5	2.5	2.4	2.5
Peak Flux Density in 1 MHz (dBW/m^2)	-110.4	-120.6	-110.7	-121.5

Detailed link budgets for the ISLs for nominal and into sun conditions are shown in Table 3.3-8. The maximum bit rate is shown. For communication at any of the lower bit rates, the transmit power is reduced accordingly. The into-sun condition occurs when the satellite geometry requires that one of the receive antennas points directly at the sun. The ISLs experience sun outages for the into-sun condition when the inter-satellite range exceeds 1 900 km. These occurrences are infrequent and predictable, and do not significantly effect system operation.

TABLE 3.3-7

GSL heavy rain link budgets

	40 DEGREE ELEVATION		90 DEGREE ELEVATIO	
	UP-LINK	DOWN-LINK	UP-LINK	DOWN-LINK
Peak Transmit Power (Watts)	49	4.6	2.15	0.55
Transmit Antenna Peak Gain (dB)	50	41	50	41
Pointing Loss (dB)	-0.5	-0.5	-0.5	-0.5
EIRP (dBW)	66.4	47.1	52.8	37.9
Frequency (GHz)	30	20	30	20
Slant Range (km)	1022	1022	700	700
Polarization Loss (dB)	0.5	0.5	0.5	0.5
Gaseous Loss (dB)	1.3	2.7	1	2.1
Rainfall Loss (dB)	19.0	9.0	9.0	4.0
Total Transmission Loss (dB)	203.0	190.9	189.4	182.0
Receive Antenna Peak Gain (dB)	41	47	41	47
Pointing Loss (dB)	-0.5	-0.5	-0.5	-0.5
Antenna Loss (dB)	2	1	2	1
Receiver Noise Figure (dB)	3.5	2.5	3.5	2.5
G/T (dB/K)	12.4	19.5	12.4	19.9
Uncoded Burst Data Rate (Mbits/sec)	1531	1531	1531	1531
Required Eb/No (dB)	10	10	10	10
Implementation Loss (dB)	2	2	2	2
Required C/No (dB-Hz)	103.8	103.8	103.8	103.8
Link Margin (dB)	0.5	0.5	0.5	0.5
Peak Flux Density in 1 MHz (dBW/m^2)	-93.3	-112.6	-103.6	-118.5

TABLE 3.3-8

ISL link budgets

	NOMINAL		INTO SUN	
	MAX RANGE	MIN. RANGE	MAX RANGE	MIN. RANGE
Peak Transmit Power (Watts)	5.5	0.0082	5.5	0.0195
Transmit Antenna Peak Gain (dB)	48	48	48	48
Pointing Loss (dB)	-0.5	-0.5	-0.5	-0.5
EIRP (dBW)	54.9	26.6	54.9	30.4
Frequency (GHz)	60	60	60	60
Slant Range (km)	2586	100	2586	100
Polarization Loss (dB)	0.5	0.5	0.5	0.5
Total Transmission Loss (dB)	196.8	168.5	196.8	168.5
Receive Antenna Peak Gain (dB)	48	48	48	48
Pointing Loss (dB)	-0.5	-0.5	-0.5	-0.5
Antenna Loss (dB)	2	2	2	2
Receiver Noise Figure (dB)	4	4	4	4
G/T (dB/K)	20.1	20.1	14.4	14.4
Uncoded Data Rate (Mbits/sec)	1531	1531	1531	1531
Required Eb/No (dB)	10	10	10	10
Implementation Loss (dB)	2	2	2	2
Required C/No (dB-Hz)	103.8	103.8	103.8	103.8
Link Margin (dB)	3.0	3.0	-2.7	1.0
Peak Flux Density in 1 MHz (dBW/m²)	-113.8	-113.9	-113.8	-110.1

4   Remarks

The NGSO FSS and MSS network described in this report features a combined service concept for satellite communications. This combining of services in one network requires studies and analyses of the intraservice and the interservice frequency sharing relationships between this network and other potential users of the same frequency bands. This document has provided information on the technical characteristics of the NGSO FSS and MSS network in sufficient detail to define the planned spectrum use by the network and to support the required sharing studies and analyses.

APPENDIX B

Co-Directional Frequency Sharing Between NGSO MSS Feeder Links and NGSO Satellite Systems (FSS and MSS, Service and Feeder Links) in the 30/20 GHz Band

1.0 Introduction:

Informal Working Group 4 (IWG-4) of the FCC Industry Advisory Committee for WRC-95 is tasked with developing a U.S. industry consensus position on proposals for preferred FSS frequency bands which could support MSS feeder link spectrum. As such, this paper presents extensive analysis and simulation results related to the feasibility of co-directional frequency sharing between NGSO MSS feeder links, and FSS and MSS service links and feeder links of other NGSO Satellite Systems. The feasibility of co-directional frequency sharing between NGSO MSS feeder links and NGSO Satellite Systems is necessary in determining the optimum choice of frequency bands for these services.

The LEO A system is used as an example of a NGSO MSS system with feeder links operating in Ka-Band. The LEOSAT-1 system is used as a representative example of a NGSO satellite service operating in Ka-Band. It has both FSS and MSS service links, and FSS and MSS feeder-links. Extensive computer simulation runs are used to calculate the statistics of the interference between the links of the two systems. The two representative systems have proposed to operate at different Ka-band frequencies and thus the analysis presented in this paper only examines the possibility of co-frequency sharing.

2. Technical Characteristics of the Satellite Systems

Table 2.1 shows the orbital parameters of the two systems. The Technical characteristics of the communication systems of both systems are shown in Table 2.2. The antenna patterns are shown in Figures 2.2 to 2.11. The NGSO Satellite Service network uses a constellation of 840 operational interlinked low-Earth orbit (LEO) satellites. The Earth's surface is mapped into a fixed grid of approximately 20,000 supercells. Each supercell is a square with sides of 160

km in length. Each supercell is further divided into 9 square cells of area 53.3 km × 53.3 km each. The network uses a combination of space, time, and frequency division multiple access techniques. At any instant in time, each fixed supercell is served by 1 of the 64 transmit and 1 of the 64 receive beams on one of the satellites. The scanning beam scans the 9 cells within the supercell with a 23.111 msec scan cycle, resulting in time division multiple access among the cells in a supercells. Physical separation and a checkerboard pattern of left and right circular polarization eliminate interference among cells scanned at the same time in adjacent supercells. Within each cell's time slot, terminals use Frequency Division Multiple Access (FDMA) on the uplink and Asynchronous Time Division Multiple Access (ATDMA) on the downlink.

	NGSO Satellite System	NGSO MSS Feeder-Link
No. of Planes	21	6
No. of Satellites Per Plane	44	11
Altitude	700 km	780 km
Inclination	98.2°	86.5°

Table 2.1 Orbital Parameters

	NGSO Satellite System			NGSO MSS
	Standard Links	Mobile Links	High Rate Links	Feeder-Links
Uplink Polarization	LHC/RHC	LHC/RHC	LHC/RHC	RHC
Downlink Polarization	LHC/RHC	LHC/RHC	LHC/RHC	RHC
Satellite Transmit Power (dBW)	18.8	18.8	-5.5 to 6.6	-22.4 to -3.2
Earth Station Transmit Power (dBW)	-20.3 to -1.9	-20.3 to -1.9	-3.8 to 16.9	-22.3 to 12
Satellite Receive Bandwidth (MHz)	0.275	0.275	800	6.25
Earth Station Receive Bandwidth (MHz)	396	99	800	6.25
Eb/No per User (dB)	8.5	8.5	12	7.7
Maximum Acceptable I_0/N_0 (dB)	-17.4	-17.4	-10.2	-13

Table 2.2 Communications Parameters

The NGSO Satellite Service network uses a wide variety of earth stations to support different kind of services and users. The Standard Earth Stations and the High Rate Earth Stations support FSS service and Feeder Links. The Mobile Earth Stations support MSS applications with the Standard Earth Stations and the High Rate Earth Stations providing the required feeder links. The three types of Earth stations are described below. Figure 2.1 depicts the data flow between them.
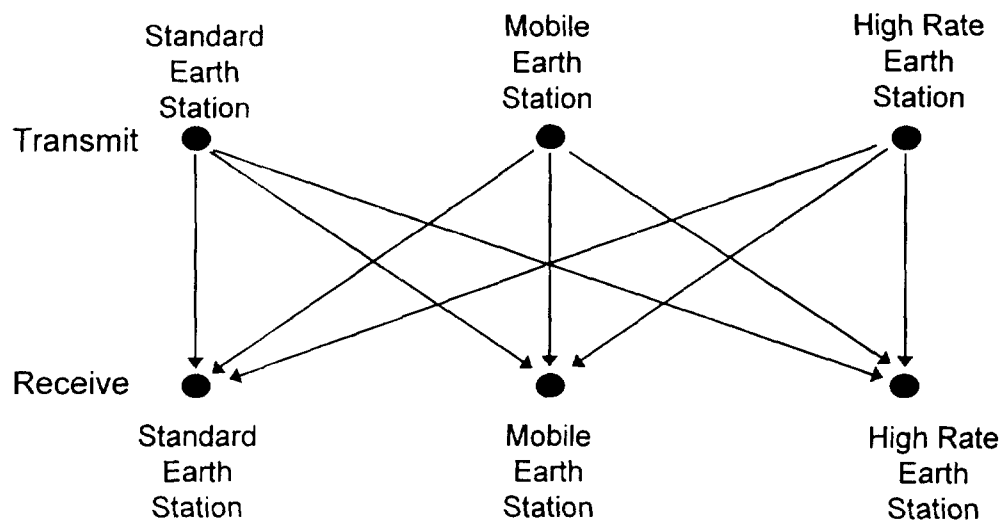
Figure 2.1 NGSO Satellite Service Network Data Flow

a. Standard Earth Stations

The Standard Earth Stations are designed to accommodate data rates from 16 kbps (Basic Channel) up to 2.048 Mbps (E1). Hundreds of these earth stations can be located within a single cell, but at any instant of time, only up to 1440 basic channel earth stations or 15 T1 rate (1.544 Mbps) earth stations or a combination of different data rate earth stations are allowed to operate simultaneously within a single cell.

Each cell within a supercell will be scanned by the satellite in a time division multiplexed manner, so the transmission is bursty with a duty cycle of about 10%. For uplinks within a cell, signals from different terminals are frequency multiplexed within the 400 MHz bandwidth available. The frequency band assigned to a certain terminal depends on the data rate the terminal requested. The downlinks operates in ATDMA manner. The satellite transmits a series of packets addressed to terminals within a cell. A terminal only selects those packets that are addressed to it. Figures 2.8 and 2.9 show the antenna patterns of the Standard Earth Station and Figure 2.6 shows the contour of the satellite antenna footprint for the Satellite Standard Link.
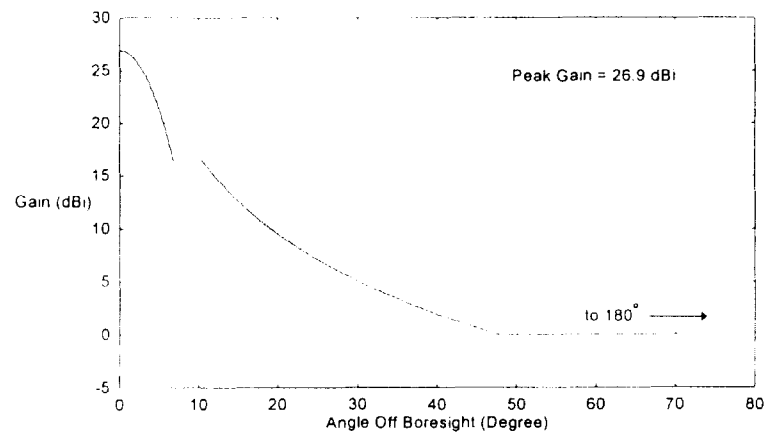
Figure 2.2 NGSO MSS Feeder-Link Satellite
Transmit Antenna Pattern
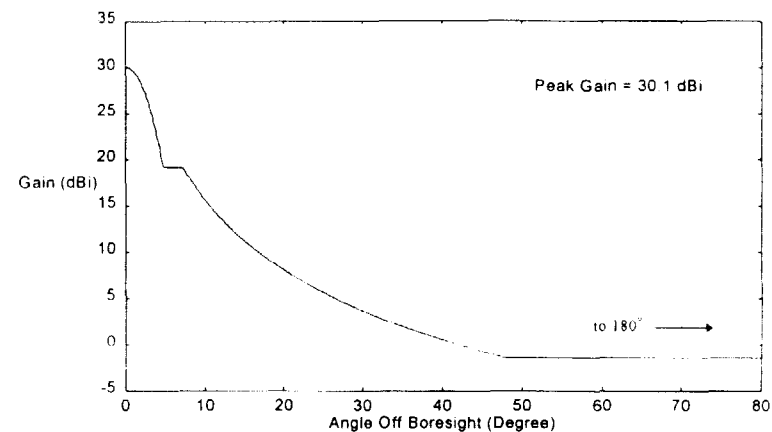
Figure 2.3 NGSO MSS Feeder-Link Satellite Receive
Antenna Pattern
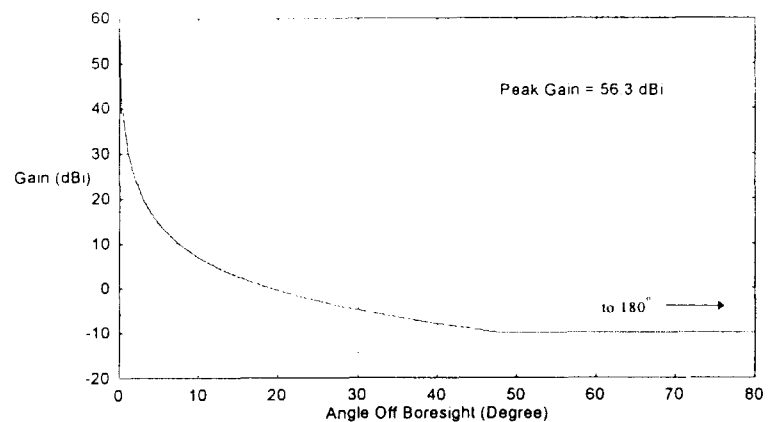
Figure 2.4 NGSO MSS Feeder-Link Earth Station
Transmit Antenna Pattern
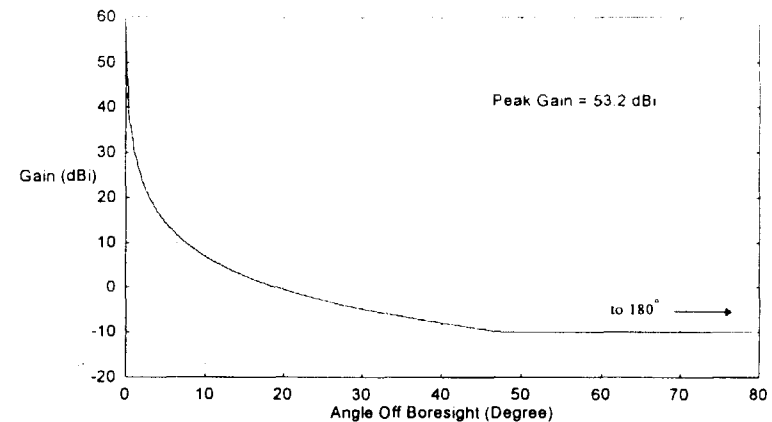
Figure 2.5 NGSO MSS Feeder-Link Earth Station
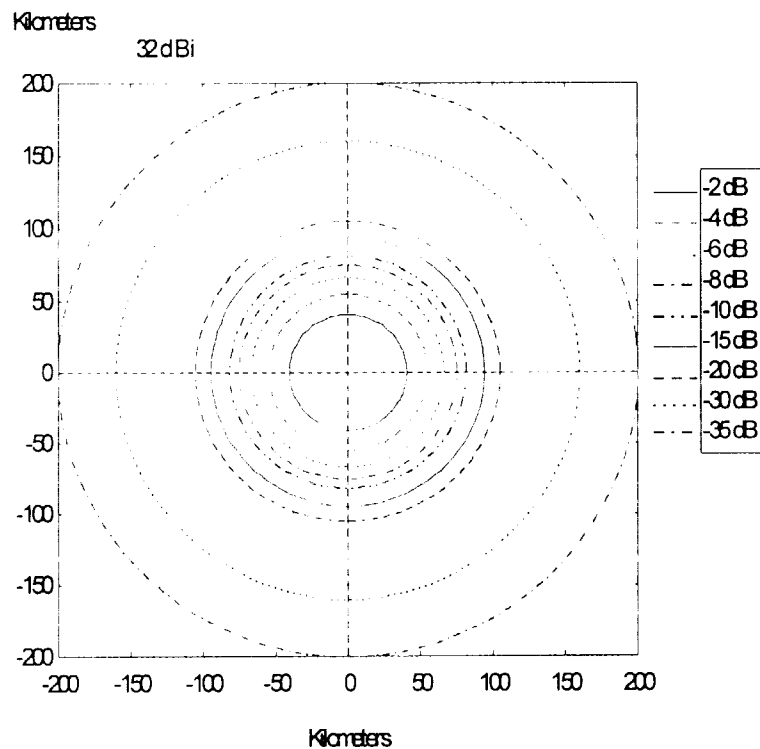Receive Antenna Pattern

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Figure 2.6 NGSO System Satellite Standard Link
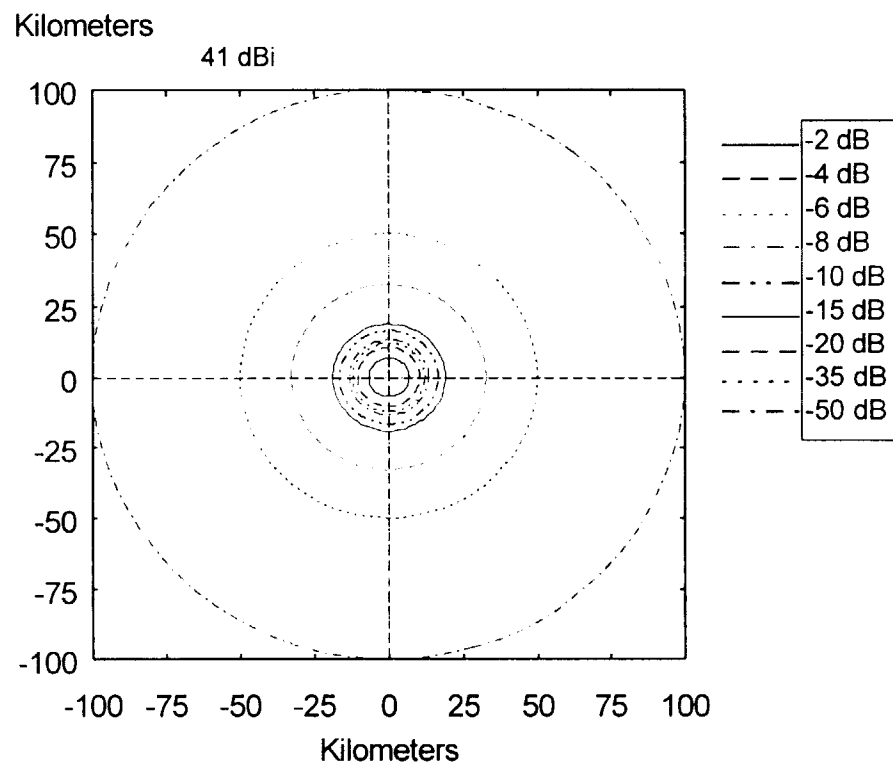and Mobile Link Transmit and Receive
Gain Contours

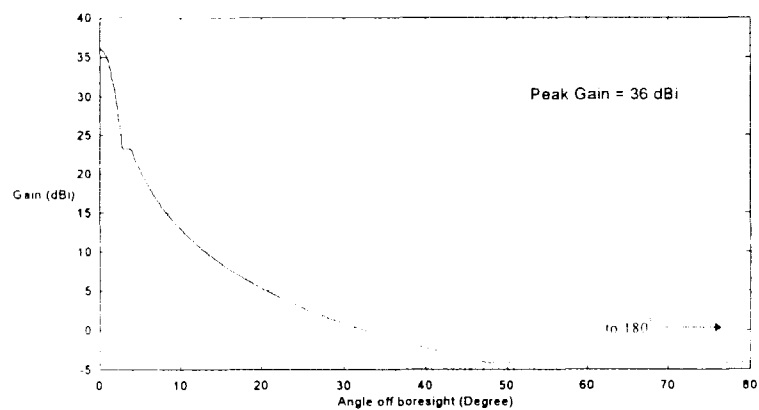Figure 2.7 NGSO System Satellite High Rate Link Transmit and
Receive Gain Pattern

Figure 2.8 NGSO Satellite System Standard Earth
Station and Mobile Earth Station Transmit Antenna
Pattern
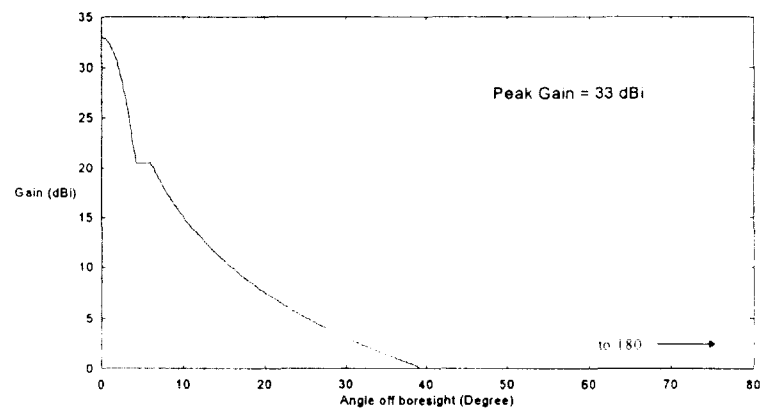
Figure 2.9 NGSO Satellite System Standard Earth
Station and Mobile Earth Station Receive Antenna
Pattern
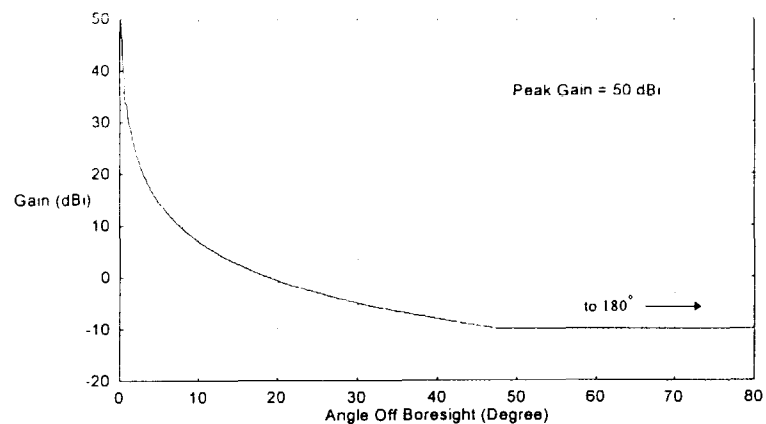
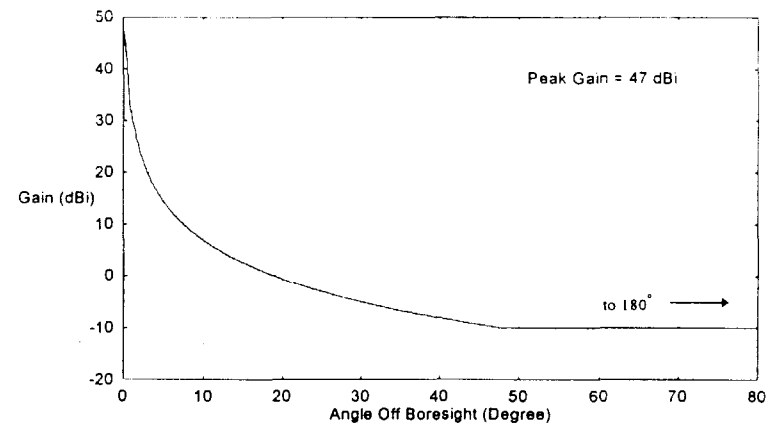Figure 2.10 NGSO Satellite System High Rate Earth
Station Transmit Antenna Pattern

Figure 2.11 NGSO Satellite System High Rate Earth
Station Receive Antenna Pattern

b. Mobile Earth Stations

The NGSO Satellite Services network also supports Mobile Earth Stations. The Mobile Earth Stations operate at multiple rates of the 16 kbps up to 2.048 Mbps (E1). The operation of the Mobile Earth Stations are similar to the Standard Earth Stations with following exceptions:
- The Mobile Earth Station can use a smaller antenna.
- The bandwidth for MSS is 100 Mhz which can accomodate up to 360 basic channels in each cell.

The antenna patterns for the Mobile Standard Terminal and the Satellite Mobile Links are the same as the Satellite Standard Links as shown in Figures 2.8, 2.9 and 2.6.

c. High Rate Earth Station

The NGSO Satellite Service network also supports a smaller number of fixed-site High Rate Earth Stations that operate at the OC-3 rate (155.52 Mbps) and multiples of this rate up to OC-24 (1.24416 Gbps). Each satellite can support up to sixteen High Rate Earth Stations within its service area. Figures 2.10 and 2.11 show the antenna patterns of the High Rate Earth Station and Figure 2.7 shows the contour of the satellite antenna footprint for the Satellite High Rate Link.

3.0 Interference Analysis

In order to calculate the complex, time-varying interference statistics between the NGSO MSS feeder links and the NGSO Satellite Service links, a detailed computer simulation program is developed. The simulation program is based on software modules that have been previously developed and tested. The results of the simulation runs were validated by simple analysis and by comparison to another independently developed simplified simulation program.

The simulation program includes the satellite orbital ephemeris and visibility characteristics as viewed from any given location on the earth. It allows for a wide range of choices in specifying the NGSO orbital parameters, link parameters, and simulation duration and step size. The output of the simulation program at each step size is the Carrier to Interference power ratio at the interfered with receiver as given by:

$$C/I = P_T^C + G_T^C(0) - PL^C - G_R^C(0) - 10 \cdot \log \sum_{\text{for all } I} 10^{P_T^I + G_T^I(\theta_{I/C}) - PL^{I/C} + G_R^C(\theta_{C/I}) - BWF^{I/C}}$$

where

P_T^C is the desired signal transmit power (dBW)

$G_T^C (0)$ is desired signal transmit antenna peak gain (dB)

PL^C is the path loss from the desired transmitter to the receiver (dB)

$G_R^C (0)$ is the receiver antenna peak gain (dB)

P_T^I is the interference signal transmit power (dBW)

$G_T^C (\theta_{I/C})$ is the interference signal transmit antenna gain in the direction of the receiver (dB)

$PL^{I/C}$ is the path loss from the interfering transmitter to the receiver (dB)

$G_R^C (\theta_{C/I})$ is the receiver antenna gain in the direction of the interfering transmitter (dB)

$BWF^{I/C}$ is a bandwidth factor equal to 0 dB if the interference signal transmit bandwidth is less than or equal to the desired receive bandwidth and it is equal to 10 Log_{10} ($BW_{transmit}$ / $BW_{receive}$) if the interference signal transmit bandwidth is greater than the desired signal receive bandwidth.

There are four possible interference cases. In each of these cases the interference statistics between the NGSO MSS feeder links and the three link types of the NGSO Satellite Service network are calculated. Figure 3.1 depicts the distribution of the NSGO Satellite Service Standard and Mobile Earth Stations around the NGSO MSS Feeder Link Earth Station. It is assumed that one earth station is collocated with the NGSO MSS Feeder Link Earth Station. Furthermore it is assumed that in other cells that are separated by 160 km there are other NGSO Service Satellite Earth Stations communicating with the NGSO satellite. A grid of 21 by 21 or a total of 441 Standard Earth Stations or Mobile Earth Stations are considered. In some of the analysis the collocated earth station is removed in the interference calculations to evaluate the sensitivity of the interference statistics to the minimum distance between a NGSO Standard or Mobile Earth Station and the NGSO MSS Feeder Link Earth Station. Figure 3.2 depicts the distribution of nine High Rate Earth Stations with one of them collocated with the NGSO MSS Feeder Link Earth Station.
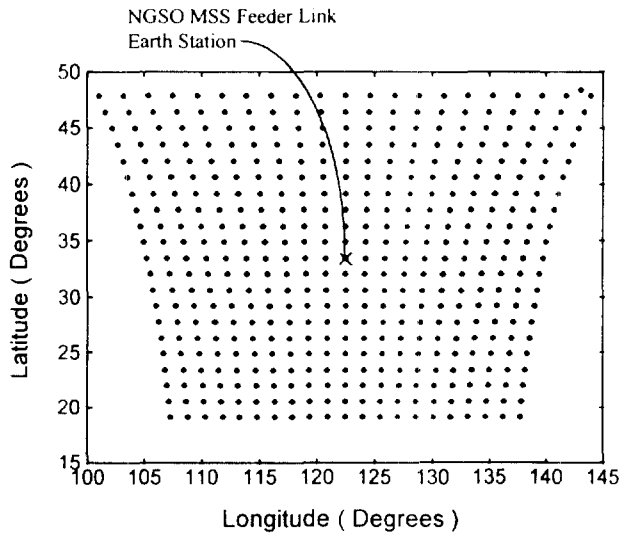
Figure 3.1: Ground Segment Distribution
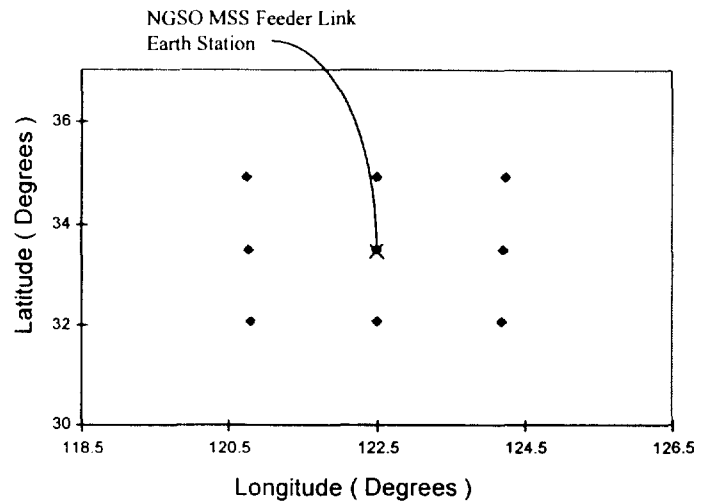of NGSO Standard Earth Stations

Figure 3.2: Ground Segment Distribution of
NGSO High Rate Earth Stations

In what follows each of the interference cases are described and the method used in calculating the interference statistics is outlined.

Case 1 : Interference from a NGSO Satellite into a NGSO MSS Feeder Link Earth Station

This case is shown in figure 3.3. At each simulation step the carrier power at the NGSO MSS Feeder Link Earth Station receiver is calculated by locating the closest satellite to the Earth Station with an elevation angle of greater than 5 degrees. It is then assumed that NGSO MSS Feeder downlink transmitter employs automatic power control to compensate for the range and atmospheric losses to achieve a C/N of 7.7 dB at the receiver.

The interference power at NGSO MSS Feeder Link Earth Station is calculated by summing the interference power received from all the NGSO satellites communicating with their corresponding earth stations. For each NGSO Earth Station the corresponding NSGO satellite that is closest to it which has elevation angle of at least 40° is found and the interference power from that satellite to the MSS Feeder Link Earth Station is calculated. The antenna discrimination from the NGSO satellite antenna is found by calculating the distance between the NGSO MSS Feeder Link Earth Station and the NGSO Earth Station communicating with the satellite.

An example interference link budget is given in Table 3.1. In this example, a single NGSO earth station (standard terminal, mobile terminal and high rate terminal) collocated with the NGSO MSS feeder link earth station is considered. The interference power is computed from a single NGSO satellite-to-earth station

link when the satellites are "in-line" at 90° elevation from the point of view of the NGSO MSS feeder link earth station.
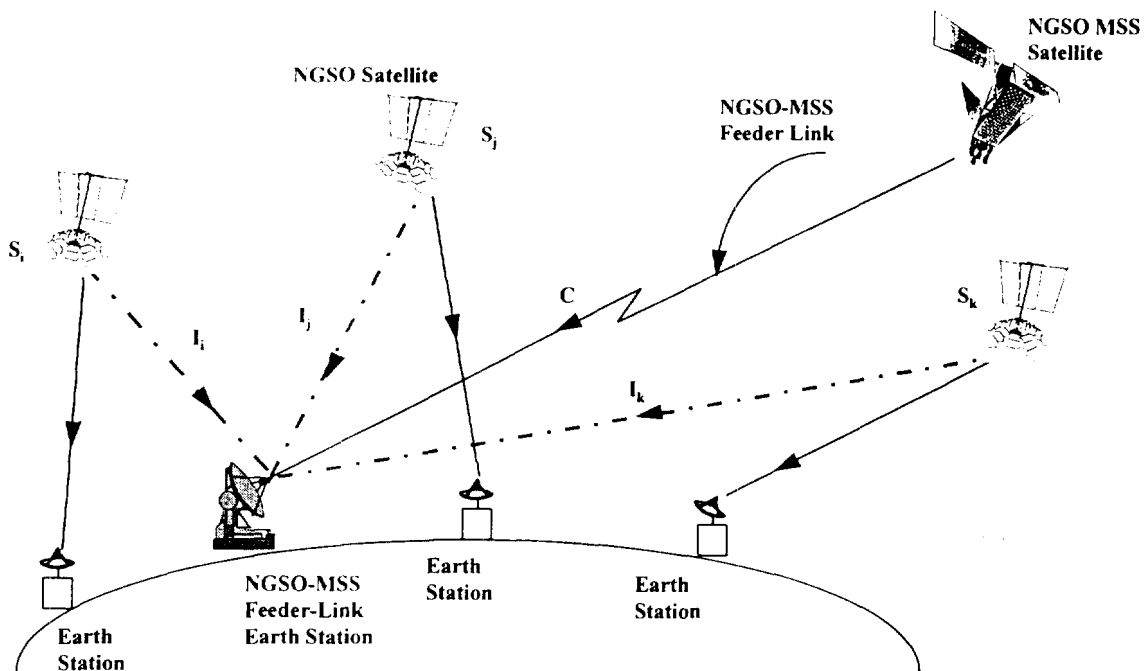

Figure 3.3 Case 1: Interference from NGSO Satellite into NGSO-MSS Feeder-Link Earth Station

Parameter	Desired NGSO MSS Feeder Link	NGSO Interference, LEO SAT-1			Units
		Standard Link	Mobile Link	High Rate Link	
+ Transmit Power	-27.9	18.8	18.8	-5.5	dBW
+ Transmit Antenna Peak Gain	26.9	29.8	29.8	41.0	dBi
= Transmitted EIRP	-1.0	48.6	48.6	35.5	dBW
- Transmission Loss	176.3	175.3	175.3	175.3	dB
+ Receiving Antenna Peak Gain	53.2	53.2	53.2	53.2	dBi
= Received Power at LEO A ES	-124.1	-73.5	-73.5	-86.6	dBW
- LEO SAT-1 Transmit BW		86.0	80.0	89.0	dB-Hz
= Interference Power Density		-159.5	-153.5	-175.6	dBW/Hz
- Thermal Noise Power Density	-200.0				dBW/Hz
= I_0/N_0 at LEO A Earth Station		40.5	46.5	24.4	dB
Required I_0/N_0 (Protection Ratio)	-13.0				dB

Table 3.1 Interference Link Budget for Case 1: Interference from NGSO Satellite into NGSO MSS Feeder Link Earth Station.

Case 2: Interference from NGSO Earth Station into a NGSO MSS Feeder Link Satellite

This case is shown in figure 3.4. The simulation procedure for this case is the same as that of case one with the exception that this case deals with the interference into the NGSO MSS Feeder Link satellite. The location of the closest NGSO MSS Feeder Link satellite is determined and then the sum of the interference from all the NGSO Earth Stations is calculated. It is assumed that the NGSO MSS feeder link employs power control so that C/N at the satellite receiver is maintained at 7.7 dB.
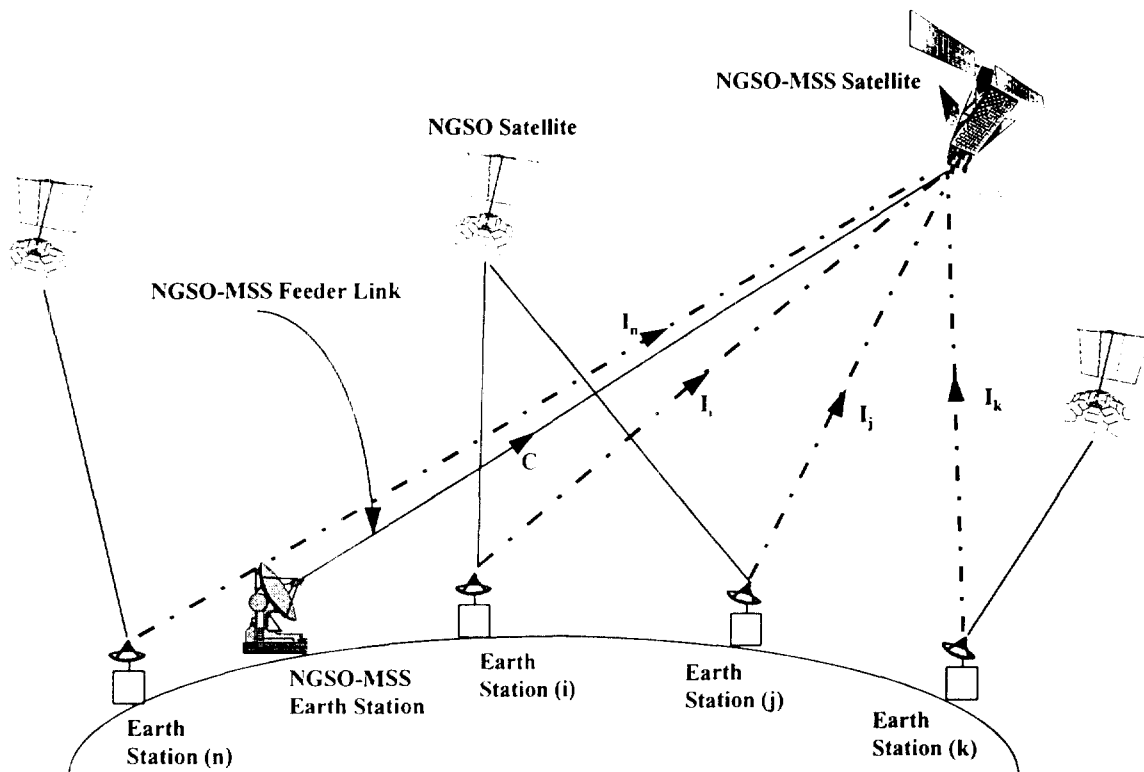

Figure 3.4 Case 2: Interference from NGSO Earth Station into NGSO-MSS Feeder-Link Satellite

An example interference link budget is given in Table 3.2. In this example, a single NGSO earth station (standard terminal, mobile terminal and high rate terminal) collocated with the NGSO MSS feeder link earth station is considered. The interference power is computed from the single ground-to-satellite link when the satellites are "in-line" at 90° elevation from the point of view of the NGSO MSS feeder link earth station.

Parameter	Desired NGSO MSS Feeder Link	NGSO Interference, LEO SAT-1			Units
		Standard Link (T1)	Mobile Link (T1)	OC24 High Rate Link	
+ Transmit Power	-28.2	-0.5	5.5	-4.0	dBW
+ Transmit Antenna Peak Gain	56.3	36.0	30.0	50.0	dB
= Transmitted EIRP	28.1	35.5	35.5	46.0	dBW
- Transmission Loss	179.8	179.8	179.8	179.8	dB
+ Receiving Antenna Peak Gain	30.1	30.1	30.1	30.1	dB
= Received Power at LEO A sat.	-121.6	-114.2	-114.2	-103.7	dBW
- LEO SAT-1Transmit BW		74.2	74.2	89.0	dB-Hz
= Interference Power Density		-188.4	-188.4	-192.7	dBW/Hz
- Thermal Noise Power Density	-197.5				dBW/Hz
= I_0/N_0 at LEO A Earth Station		9.1	9.1	4.8	dB
Required I_0/N_0 (Protection Ratio)	-13.0				dB

Table 3.2 Interference Link Budget for Case 2: Interference from NGSO Satellite Earth Station into NGSO MSS Feeder Link Satellite.

Case 3: Interference from a NGSO MSS Feeder-Link Earth Station into NGSO Satellite
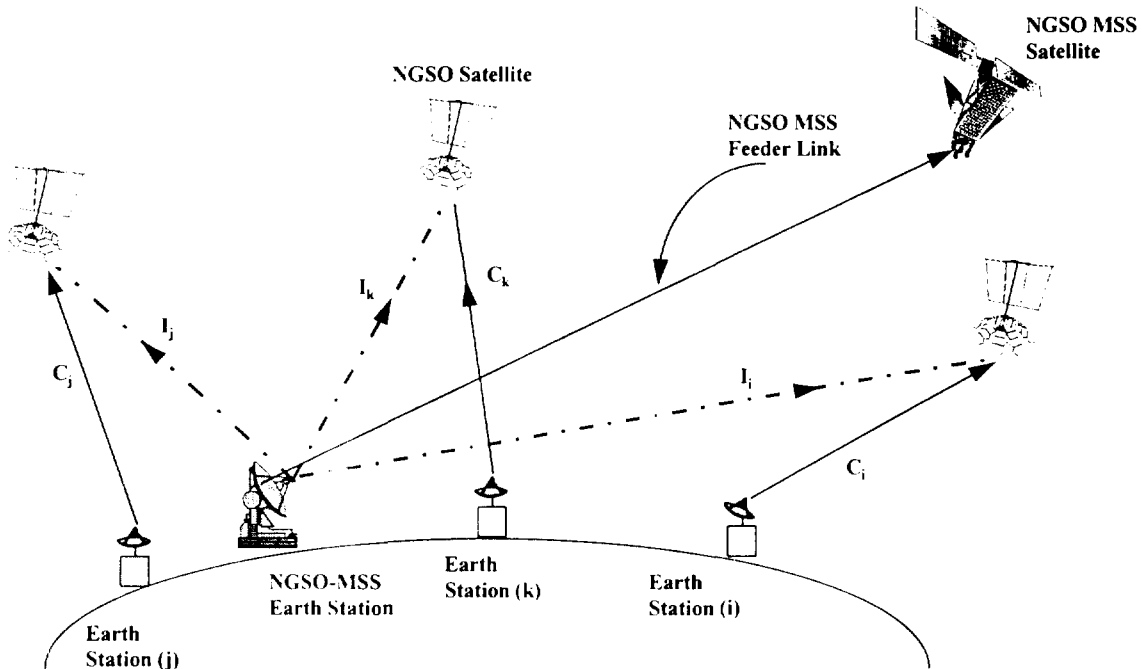

Figure 3.5 Case 3: Interference from NGSO-MSS Feeder-Link Earth Station into NGSO Satellite

This case is shown in figure 3.5. In this case the location of the NGSO satellite communicating with each earth station is calculated. The location of the NGSO MSS satellite is also obtained. The transmitted power of the NGSO MSS Feeder Link Earth Station is calculated such that the C/N at the NGSO MSS satellite is constant. Then based on the location of the satellites the I_0/N_0 at each NGSO satellite is calculated.

An example interference link budget is given in Table 3.3. In this example, the interference source, the NGSO MSS feeder link earth station, is considered collocated with the desired link NGSO earth station (standard terminal, mobile terminal and high rate terminal). The satellites of both systems are "in-line" at 90° elevation from the point of view of the NGSO earth station.

Parameter	Desired, LEO SAT-1			Interference	Units
	Standard Link (16K)	Mobile Link (16K)	OC24 High Rate Link	NGSO MSS Feeder Link	
+ Transmit Power	-20.3	-14.3	-3.8	-28.2	dBW
+ Transmit Antenna Peak Gain	36.0	30.0	50.0	56.3	dB
= Transmitted EIRP	15.7	15.7	46.2	28.1	dBW
- Transmission Loss	178.9	178.9	178.9	178.9	dB
+ Receiving Antenna Peak Gain	29.8	29.8	41.0		dB
= Received Carrier Power	-133.4	-133.4	-91.7		dBW
Received Interference Power	-121.0	-121.0	-109.8		dBW
- Transmit BW	54.4	54.4	89.0	68.0	dBHz
= Interference Power Density	-189.0	-189.0	-198.8*		dBW/Hz
- Thermal Noise Power Density	-200.5	-200.5	-200.5		dBW/Hz
= I_0/N_0 at LEO A Earth Station	11.5	11.5	1.7		dB
Required I_0/N_0 (Protection Ratio)	-17.4	-17.4	-10.2		dB

Table 3-3 Interference Link Budget For Case 3: Interference from NGSO MSS Feeder Link Earth Station into NGSO Satellite.

Case 4: Interference from NGSO MSS Feeder-Link Satellite into NGSO Earth Station

This case is shown in figure 3.6. Analysis of the "in-line" interference in this case shows that the carrier-to-interference ratio does not fall below the desired system performance level. Therefore no interference is observed in this case.

An example interference link budget is given in Table 3.4. In this example, the interferer, NGSO MSS satellite is considered transmitting to a feeder link earth station collocated with the NGSO earth station (standard terminal, mobile

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* Assume the interference power is spread over the entire desired signal band with total power unchanged.

terminal and high rate terminal) of the desired link. The satellites of both systems are "in-line" at 90° elevation from the point of view of the NGSO earth station.
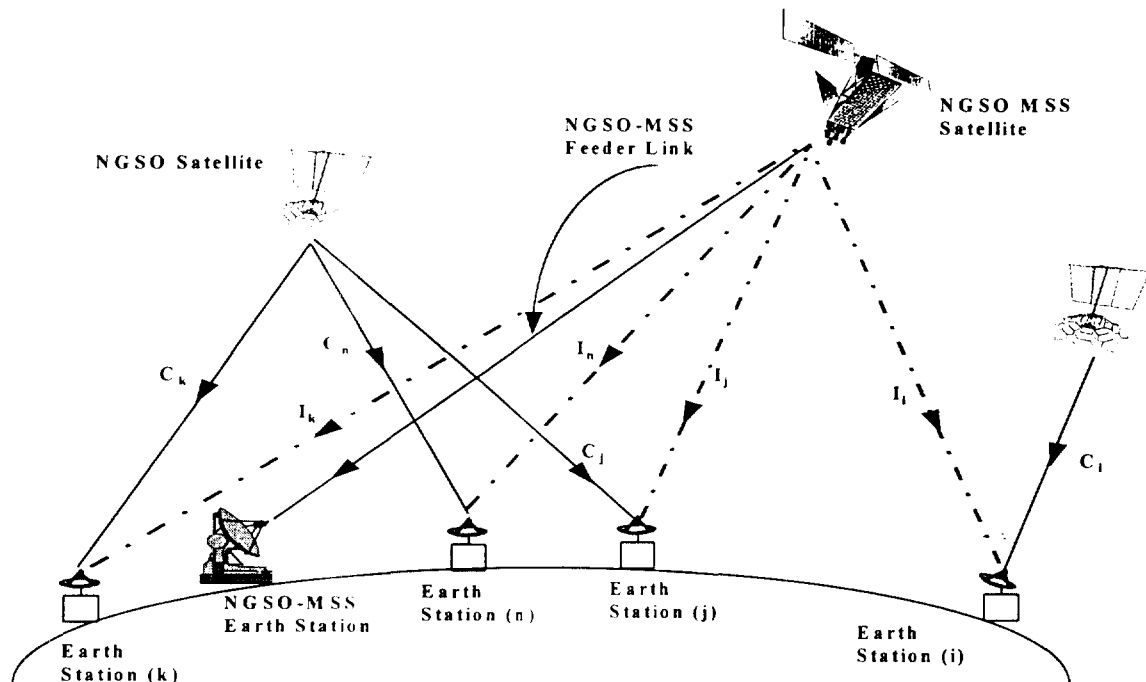

Figure 3.6 Case 4: Interference from NGSO-MSS Feeder-Link Satellite into NGSO Earth Station

Parameter	Desired			Interference	Units
	Standard Link	Mobile Link	High Rate Link	(LEO A) Earth Station	
+ Transmit Power	18.8	18.8	-5.5	-27.9	dBW
+ Transmit Antenna Peak Gain	29.8	29.8	41.0	26.9	dBi
= Transmitted EIRP	48.6	48.6	35.5	-1.0	dBW
- Transmission Loss	175.3	175.3	175.3	176.3	dB
+ Receiving Antenna Peak Gain	33.0	27.0	47.0		dB
= Received Carrier Power	-93.7	-99.7	-92.8		dBW
Received Interference Power	-144.3	-150.3	-130.3		dBW
- Transmit BW	86.0	80.0	89.0	68.0	dB-Hz
= Interference Power Density[+]	-230.3	-230.3	-219.3		dBW
- Thermal Noise Power Density	-202.9	-202.9	-202.9		dBW/Hz
= I_0/N_0 at LEO A Earth Station	-27.4	-27.4	-16.4		dB
Required I_0/N_0 (Protection Ratio)	-17.4	-17.4	-10.2		dB

Table 3.4 Interference Link Budget For Case 4: Interference from NGSO MSS Feeder Link Satellite into NGSO Satellite Earth Station.

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[*] Assume the interference power is spread over the entire desired signal band with total power unchanged.

4.0 Simulation Results

The simulation program described in the previous section is used to calculate the interference statistics between the feeder links of a NGSO MSS system, and the FSS and MSS service and feeder links of another NGSO satellite system. The simulation statistical results discussed in this paper are based on a simulation period of one year in order to average out any short-term fluctuations. The output of the simulation program is the time history of the I_0/N_0 at each simulation step. In order to gain additional insight and understanding of the simulation results, a post processor program is developed that calculates and plots the following statistics:

a) I_0/N_0 time history
b) I_0/N_0 probability density function and cumulative probability distribution function
c) Interference event duration statistics
d) Interval between interference events statistics

The interference between the NSGO MSS feeder links and three different NGSO satellite system links are considered.

1) NGSO MSS feeder links and the NGSO satellite system standard earth station links (FSS and MSS feeder links, and FSS service links)

The results of this simulation for case 1 is shown in figures 4.1 to 4.8. Figures 4.1 to 4.4 show the results when there is a standard earth station collocated with the NGSO MSS feeder link ground station. In this case the probability of interference is 4.3%. Figures 4.4 to 4.8 show the statistics when there is a 160 km separation between the NGSO standard earth station and the MSS feeder link ground station. In this case the probability of interference reduces to 1.1%. Figures 4.9 through 4.16 show the statistics of interference for case 2. In case 3, the probability is even smaller. The statistics of simulation results are given in figure 4.17 and 4.18. Only the case when there is a standard earth station collocated with the NGSO MSS feeder link ground station is considered for.

2) NGSO MSS feeder links and the NGSO mobile earth station links (MSS service links)

The statistics of interference for case 1 are shown in figures 4.19 through 4.26. The interference event in this case occurs more often. For example when one mobile station is collocated with the NGSO MSS feeder link ground station the probability of interference event is 20 %. The interference statistics of the mobile

terminal for case 2 and case 3 is similar to the statistics of the standard terminal and are shown.

3) NGSO MSS feeder links and NGSO high rate earth station links (FSS and MSS feeder links, and FSS service links)

The probability of interference between the NGSO MSS feeder link and the NGSO high rate earth station links is very small. From Figure 4.27 through 4.32 it can be seen that the probability of interference event for case 1 is 0.14%, for case 2 is 0.005% and for case 3 is almost zero. The number of interference events occurred during the simulation period is too small and reliable statistics can not be obtained from the data.

Table 4.1 summarizes the results of the simulation runs.